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Iodine(III)-Mediated Fluorination/Semipinacol Rearrangement Cascade of 2-Alkylidenecyclobutanol Derivatives: Access to β-Monofluorinated Cyclopropanecarbaldehydes

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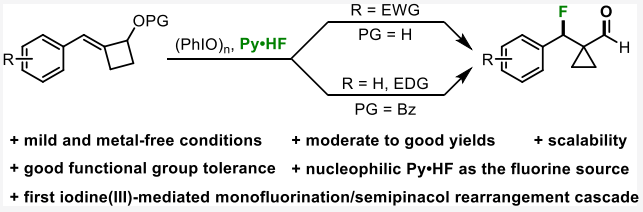
ABSTRACT: A hypervalent iodine(III)-mediated ring-contractive fluorination reaction of 2-alkylidenecyclobutanol derivatives is presented. The protocol allows the facile synthesis of β-monofluorinated cyclopropanecarbaldehydes via a fluorination/semipinacol rearrangement cascade using nucleophilic Py·HF as the fluorine source. For challenging electron-rich arene substrates, the installation of a protecting group on the free alcohol is pivotal for maintaining the reaction efficiency. The synthetic utility was demonstrated by the scalability of this reaction and further transformations of the products.



INTRODUCTION

Fluorinated organic compounds are indispensable for modern pharmaceuticals, agrochemicals, and materials sciences, and approximately 20−25% of all pharmaceuticals and agrochemicals on the market today incorporate at least one fluorine atom.[1] The introduction of fluorine into molecules frequently modulates the biological properties of parent compounds, such as the metabolic stability, lipophilicity, binding affinity, and bioavailability.[2] Despite its importance, only 30 naturally occurring organofluorides have been identified to date.[3] As such, substantial research effort has been devoted to their syntheses.[4] Although a diverse array of methods have been developed, especially in the realm of aryl fluoride synthesis, few methods exist for the synthesis of alkyl fluorides bearing a readily transformable functionality, which is important for allowing rapid assembly of complex fluorine-containing molecules.[5] In this context, fluorinated carbonyl compounds[6,7] are of particular value for organofluoride synthesis because of the flexible versatility of a carbonyl group in synthetic transformations, such as reduction, olefination, and the aldol reaction.

Semipinacol rearrangement[8] has emerged as an efficient and powerful tool for the synthesis of β-functionalized carbonyl compounds starting from allylic alcohols. Mechanistically, the addition of an electrophile to the C−C double bond generates the corresponding carbocation intermediate, followed by a Wagner−Meerwein migration (Scheme 1a). Using this strategy, several groups have realized β-fluorocarbonyl synthesis with different fluorine reagents.[9−12] For instance, with Selectfluor as the fluorine source, Tu[9a] and Alexakis[10] independently disclosed an enantioselective fluorination/semipinacol rearrangement cascade reaction to deliver these products via aryl- or alkyl-migration, respectively (Scheme 1b). Starting from H-/alkyl-substituted cyclic allylic alcohols, Zhao reported β-fluoroketone synthesis using NFSI as the fluorine source through a hydride migration process (Scheme 1b).[11] Interestingly, in Zhao's work, when an aryl-substituted cyclic allylic alcohol was used, electrophilic fluorination generated more stable benzylic carbocation followed by C−C bond cleavage to stereoselectively produce *Z*-fluoroalkene (Scheme 1c).[11] Notably, in these cases, all of the fluorine sources are electrophilic fluorine reagents.

In recent years, hypervalent iodine(III)-mediated oxidative fluorination[13] reactions of olefins have proven to be excellent and efficient methods for accessing diverse fluorinated molecules, such as monofluorinated[14] and 1,2-;[15] 1,3-;[16] and *gem*-difluorinated[17] compounds. In these reactions, stable and readily available nucleophilic fluorine reagents (e.g., KF, Py·HF, and $BF_3{\cdot}Et_2O$) are usually used as fluorine sources. We have been interested in organofluoride synthesis[18] and recently reported an iodine(III)-mediated *gem*-difluorination reaction of alkenyl boronates with Py·HF,[18a] in which a regioselective 1,2-fluoroiodination of the C−C double bond led to the formation of a benzyl fluoride intermediate, followed by observed aryl migration. In this respect, we envisioned that if styrene substrates bearing a free or protected hydroxyl group at

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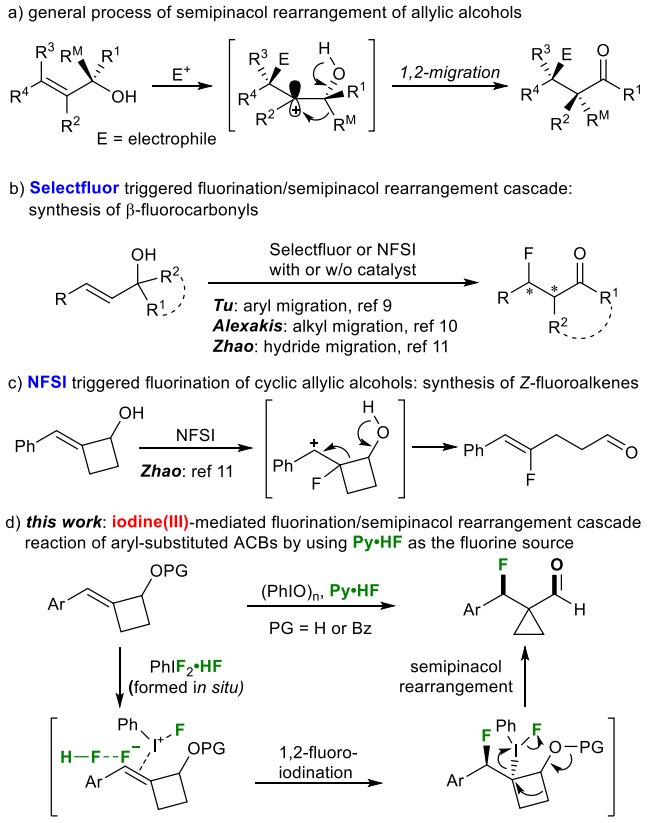
Scheme 1. Semipinacol Rearrangement and Fluorination of Allylic Alcohols



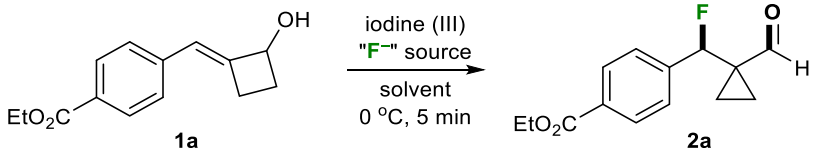
the allylic position were used, the following semipinacol-type rearrangement instead of aryl migration might occur to give β-fluorocarbonyl products (Scheme 1d).[13] Herein, we report our realization of a $(PhIO)_n$-mediated monofluorination/semipinacol rearrangement cascade reaction of aryl-substituted 2-alkylidenecyclobutanol derivatives (ACBs)[19] for the synthesis of β-monofluorinated cyclopropanecarbaldehydes using commercially available Py·HF as the fluorine source. The reaction proceeds under mild and metal-free reaction conditions, and broad functional group tolerance and moderate to good yields are observed.

RESULTS AND DISCUSSION

Initially, the monofluorination/semipinacol rearrangement cascade reaction of phenyl-substituted ACB **1a** bearing an ester group was studied by examining different fluorine sources in the presence of $(PhIO)_n$ (1.5 equiv) as the hypervalent iodine(III) reagent in toluene at 0 °C (Table 1). Although the use of Et_3N·HF, CsF, or DAST led to no reaction (entries 1 and 2), the use of Py·HF (24 equiv) successfully produced the expected monofluorination/semipinacol rearrangement product **2a** in 68% yield (entry 3). Notably, the reaction proceeded extraordinarily quickly and was completed within 5 min. Other hypervalent iodine(III) reagents tested, such as phenyliodine(III) diacetate (PIDA) or phenyl-iodine(III) bis(trifluoroacetate) (PIFA), exhibited less efficiency (entries 4 and 5). Further screening revealed that toluene was the optimal solvent (entries 6−8). The loadings of fluorine sources and hypervalent iodine(III) reagents were also examined. Either decreasing or increasing the Py·HF loading produced lower yields (44 and 35%; entries 9 and 10, respectively). The use of 1.2 equiv of $(PhIO)_n$ gave a diminished yield of 48%, whereas increasing the $(PhIO)_n$ loading to 2.0 equiv did not improve the yield (entries 11 and 12). Inferior results were obtained by increasing the reaction temperature to 25 °C (entry 13). A lower temperature of −20 °C resulted in the incomplete conversion of **1a**, even by prolonging the reaction time to 3 h (entry 14).

With the optimized conditions in hand (Table 1, entry 3), the scope of the cascade reaction with regard to electron-poor

Table 1. Optimization of Reaction Conditions[a]



entry	iodine(III)	F^- (equiv)	solvent	yield (%)[b]
1	$(PhIO)_n$	Et_3N·HF (24)	toluene	0
2	$(PhIO)_n$	CsF or DAST (5)	toluene	0
3	$(PhIO)_n$	Py·HF (24)	toluene	70 (68)
4	PIDA	Py·HF (24)	toluene	61
5	PIFA	Py·HF (24)	toluene	32
6	$(PhIO)_n$	Py·HF (24)	DCM	52
7	$(PhIO)_n$	Py·HF (24)	MeCN	0
8	$(PhIO)_n$	Py·HF (24)	CCl_4	66
9	$(PhIO)_n$	Py·HF (16)	toluene	44
10	$(PhIO)_n$	Py·HF (32)	toluene	35
11[c]	$(PhIO)_n$	Py·HF (24)	toluene	48
12[d]	$(PhIO)_n$	Py·HF (24)	toluene	62
13[e]	$(PhIO)_n$	Py·HF (24)	toluene	34
14[f]	$(PhIO)_n$	Py·HF (24)	toluene	30

[a]General reaction conditions: **1a** (0.2 mmol, 1.0 equiv), hypervalent iodine(III) (0.3 mmol, 1.5 equiv), F^- (5−32 equiv), solvent (1.0 mL), 0 °C, 5 min. [b]Yields determined via ^1H NMR spectroscopy using *p*-iodoanisole as the internal standard; isolated yield in parentheses. [c]$(PhIO)_n$ (1.2 equiv). [d]$(PhIO)_n$ (2.0 equiv). [e]25 °C. [f]−20 °C, 3 h.

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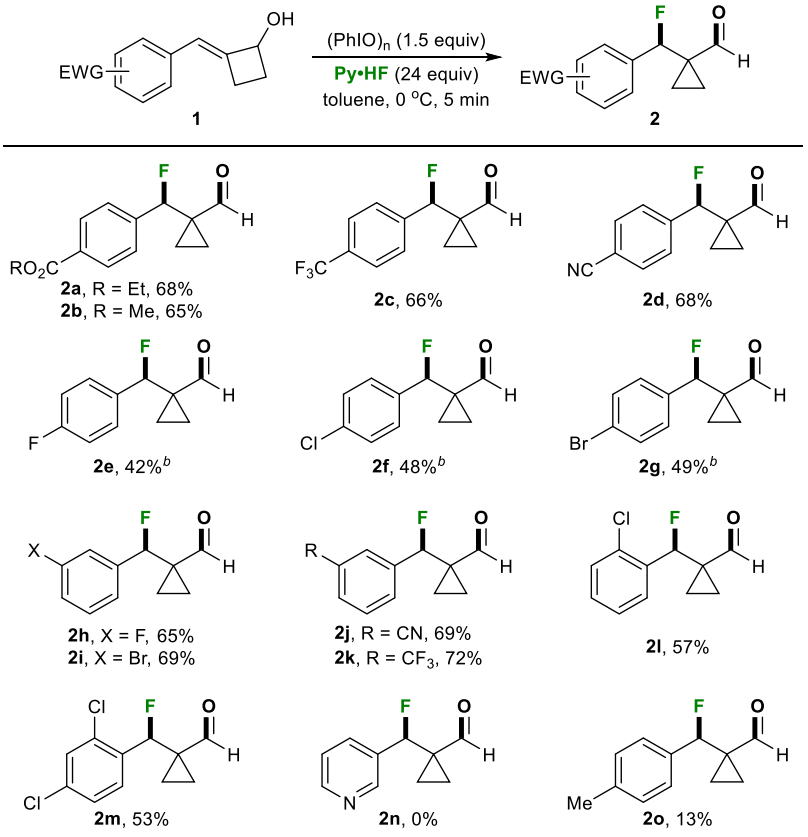
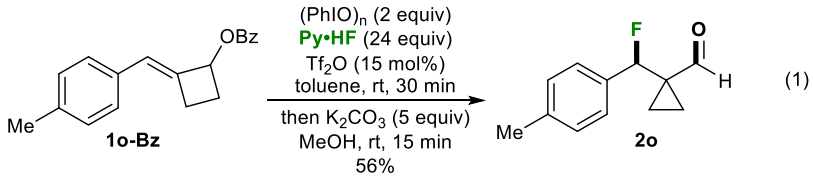
Scheme 2. Substrate Scope of Electron-Poor Arene-Substituted ACBs[a]



[a]General reaction conditions: **1** (0.2 mmol), $(PhIO)_n$ (1.5 equiv), Py·HF (24 equiv), toluene (1.0 mL), 0 °C, 5 min. [b]2.0 equiv of $(PhIO)_n$ was used.



arene-substituted ACBs was first explored. As shown in Scheme 2, a variety of commonly encountered electron-withdrawing substituents on the phenyl ring were well tolerated. Thus, irrespective of the substituted position, substituents such as ester (**2a**, **2b**), trifluoromethyl (**2c**, **2k**), cyano (**2d**, **2j**), fluoro (**2e**, **2h**), chloro (**2f**, **2l**, **2m**), and bromo (**2g**, **2i**) furnished the corresponding products in moderate to good yields (42−72%). It is noteworthy that the use of substrates bearing an ester, CN, or halides provides a platform for further manipulations. However, the reaction of the electron-poor pyridyl-substituted ACB (**1n**) did not give the corresponding *β*-monofluorinated cyclopropanecarbaldehyde, probably because of the strong coordination of the nitrogen atom within the substrate to hydrogen fluoride. Of note, the substituent at the ortho position of the benzene ring did not hamper the reactivity (**2l**, **2m**). Next, the scope of electron-rich arene-substituted ACBs was also examined. Disappointedly, although all the substrate had been consumed, a lower yield of 13% was obtained when a *para*-tolyl-substituted ACB **1o** was used under standard conditions, probably due to the strong background iodine(III)-mediated arene oxidation reaction.[20] To solve this issue, we sought to decrease the electron density of the arene ring or avoid the undesired interactions between the alcohol moiety and I(III) species by protecting the free hydroxyl group with an electron-withdrawing group and tuning the electrophilicity of the hypervalent iodine reagent by introducing a Lewis acid[21] into the system.

After extensive exploration (for details, see Supporting Information), we could obtain the desired contractive fluorination product **2o** with an acceptable yield of 56% by reaction of benzoyl-protected substrate **1o-Bz** under the conditions of $(PhIO)_n$ (2.0 equiv), Py·HF (24 equiv), and Tf_2O (15 mol %) in toluene at room temperature, followed by deprotection with K_2CO_3 in methanol (eq 1). Thus, several benzoyl-protected electron-rich arene-substituted ACBs, **1-Bz**, were synthesized and examined under the newly established reaction conditions. As illustrated in Scheme 3, the reaction proceeded smoothly to give the corresponding monofluorinated aldehydes in reasonable yields. Substrates bearing a methyl group, regardless of the position on the benzene ring, provided desired products **2o**−**2q** in moderate yields (45−56%). Steric hindrance at the 2-position of the benzene ring was tolerated well (**2q**). Moreover, other electron-donating and electron-neutral substituents, such as *i*Pr- (**2r**), *t*Bu- (**2s**),

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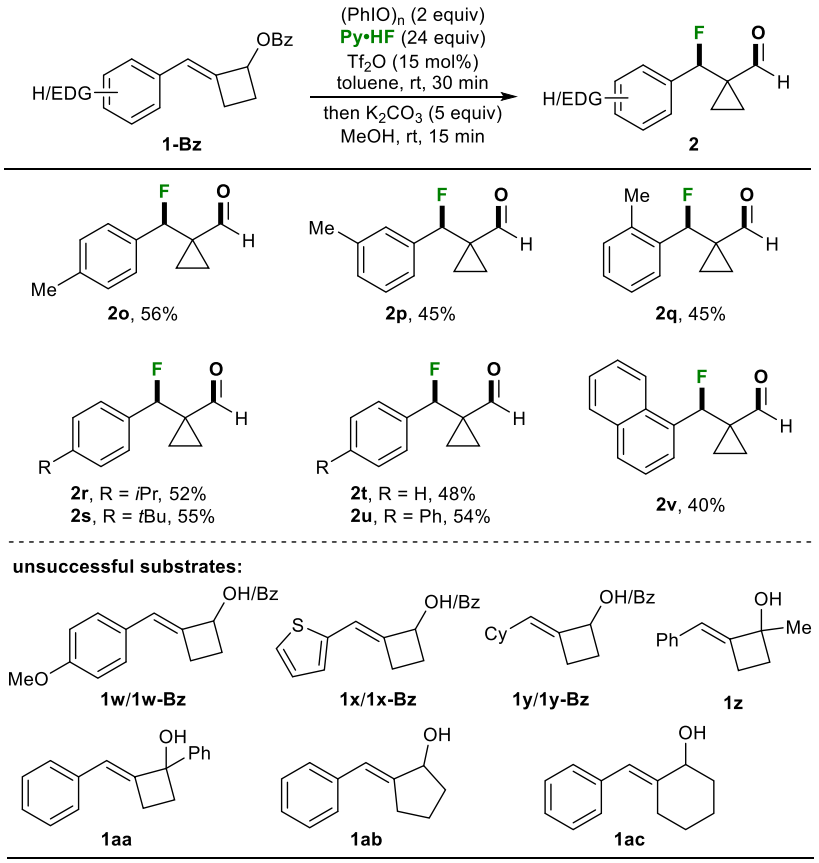
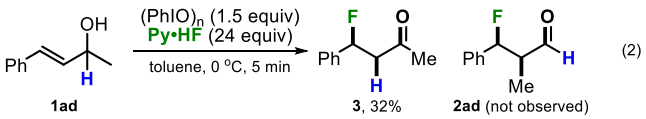
Scheme 3. Substrate Scope of Bz-Protected Electron-Rich Arene-Substituted ACBs[a]



[a]General reaction conditions: **1-Bz** (0.2 mmol), $(PhIO)_n$ (2.0 equiv), Py·HF (24 equiv), Tf_2O (15 mol %), toluene (1.0 mL), rt, 30 min; then, K_2CO_3 (5 equiv), MeOH (3 mL), rt, 15 min.

H- (**2t**), and Ph- (**2u**), were also compatible with the reaction conditions. Notably, the reaction of the naphthyl-substituted ACB **1v-Bz** produced the desired product in 40% yield. Unfortunately, the current reaction conditions were incompatible with strongly electron-rich arene- or alkyl-substituted ACBs, regardless of whether they were protected with Bz. For instance, the use of *p*-methoxyphenyl-, 2-thienyl-, or cyclohexyl-substituted ACBs (**1w**−**1y**, respectively) gave no trace of the desired products. The reaction of tertiary alcohol **1z** or **1aa** also failed to deliver the desired contractive product probably due to steric hindrance. Other cyclic alcohols such as 2-benzylidenecyclopentanol (**1ab**) and 2-benzylidenecyclohexanol (**1ac**) were not suitable for the present cascade reaction and gave a complex mixture. Finally, a simple acyclic allylic alcohol was also investigated. Interestingly, when 4-phenylbut-3-en-2-ol (**1ad**) was subjected to the reaction conditions, the expected methyl-migrated product aldehyde **2ad** was not observed. Instead, ketone **3** was isolated as the sole product in 32% yield, which should be formed via *β*-fluorination, followed by 1,2-hydride migration (eq 2).



(2)

A gram-scale synthesis was performed to demonstrate the synthetic practicality of this reaction. Thus, 1.03 g of the *β*-monofluorinated cyclopropanecarbaldehyde **2b** was obtained in 62% yield under standard reaction conditions (Scheme 4A). In addition, the synthetic decoration of the formed products led to other fluorine-containing structures. As shown in Scheme 4B, the formyl group in **2b** could be chemoselectively reduced using $NaBH_4$ to give alcohol **4** in 93% yield. On the other hand, upon treatment with oxone in *N*,*N*-dimethylformamide (DMF) or MeOH, the formyl group could be easily converted to the corresponding carboxyl acid **5** or methyl ester **6** with good efficiency, respectively. The Wittig olefination of the carbonyl group smoothly provided the vinylcyclopropane core **7**, which is frequently used as a radical probe in radical mechanism studies.[22] In addition, reductive amination produced aniline derivative **8** in 86% yield. As a final example, the use of chiral iodine(III) **9**[17a,d] rendered an enantioselective (70.8% ee) monofluorination reaction in 54% yield (Scheme 4C).

■ CONCLUSIONS

In summary, by means of a hypervalent iodine(III)-mediated fluorination/semipinacol rearrangement cascade, we have achieved a ring-contractive monofluorination reaction of ACBs using nucleophilic Py·HF as the fluorine source in the presence of $(PhIO)_n$. The method enables the facile synthesis of *β*-monofluorinated cyclopropanecarbaldehydes with different systems depending on the electronic properties of the substituents on the benzene ring. The approach occurs under mild and metal-free conditions with good functional group tolerance and moderate to good yields being observed. The

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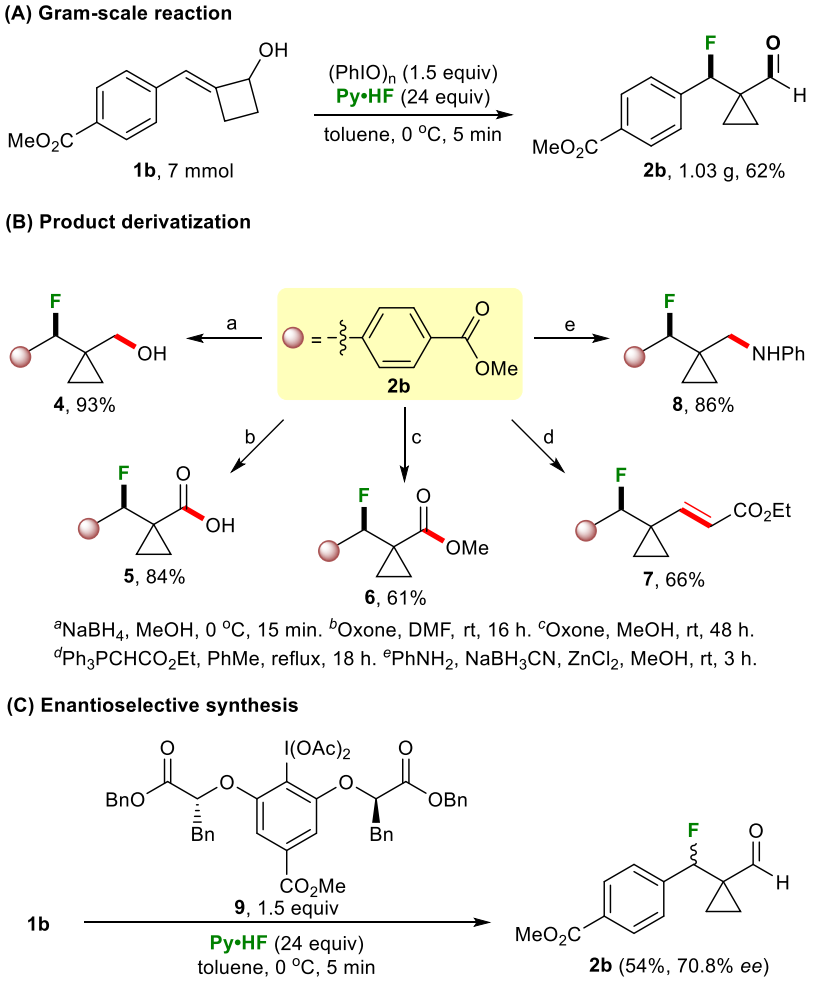
Scheme 4. Gram-Scale Synthesis and Product Derivatization



synthetic utility was demonstrated by the scalability of this reaction and further transformations of the products to a variety of fluorine-containing molecules.

EXPERIMENTAL SECTION

General Information. The solvents used were dried by distillation over the drying agents indicated in parentheses and were transferred under argon: dichloromethane (CaH_2) and tetrahydrofuran (Na-benzophenone). Toluene, DMF, methanol, ethanol, acetonitrile, and carbon tetrachloride (CCl_4) were purchased from Energy-Chemical. Commercially available chemicals were obtained from commercial suppliers and used without further purification unless otherwise stated. Proton (^1H), fluorine (^{19}F), and carbon (^{13}C) NMR spectra were recorded at 500 (or 400), 471 (or 376), and 126 (or 101) MHz spectrometers, respectively. The following abbreviations are used for the multiplicities: s: singlet, d: doublet, t: triplet, q: quartet, m: multiplet, dd: doublet of doublet, and br s: broad singlet for proton spectra. Coupling constants (J) are reported in hertz (Hz). High-resolution mass spectra (HRMS) were recorded on a BRUKER VPEXII spectrometer with EI and ESI modes unless otherwise stated. The enantioselectivities were determined by high-performance liquid chromatography (HPLC) analysis on WATERS e2695 using Chiralpak IA and OD-H columns. Analytical thin layer chromatography (TLC) was performed on Polygram SIL G/UV254 plates. Visualization was accomplished with short-wave UV light and 2,4-dinitrophenylhydrazine or $KMnO_4$ staining solutions, followed by heating. Flash column chromatography was performed using silica gel (200−300 mesh) with solvents distilled prior to use.

Benzylidenecyclobutanols **1** were prepared according to previously described methods,[23] and the spectral data are identical to those previously reported[24] for compounds **1e**, **1f**, **1g**, **1h**, **1i**, **1l**, **1o**, **1p**, **1q**, **1r**, **1s**, **1t**, **1v**, **1w**, **1x**, and **1y**.

General Procedure (A) for the Preparation of Substrates 1. To a 100 mL round-bottomed flask were added $Ca(OH)_2$ (74.1 mg, 1.0 mmol, 10 mol %), aldehydes (10.0 mmol, 1.0 equiv), cyclobutanone (30.0 mmol, 3.0 equiv), and anhydrous EtOH (15 mL) sequentially. The reaction was then heated at reflux in an oil bath under a N_2 atmosphere for 24 h. Then, the solvent was evaporated in vacuo, and the mixture underwent flash chromatography to afford the corresponding crude α,β-unsaturated cyclobutanone products; without further purification, the crude mixture was dissolved in 15 mL of MeOH, and $NaBH_4$ (1.51 g, 40.o mmol, 4.0 equiv) was added at 0 °C. After a reaction time of 2 h, the solvent was evaporated in vacuo and purified by flash chromatography to get the products **1**.

General Procedure (B) for the Preparation of Substrates 1-Bz. A 50 mL over-dried round-bottom flask with a stir bar was capped with a septum and cooled under vacuum and backfilled with argon. To the flask were added 10 mL of dry DCM, the corresponding substrates **1** (1.0 mmol), pyridine (0.12 mL, 1.2 equiv), and 4-dimethylaminopyridine (6.1 mg, 0.05 equiv). The flask was placed in an ice bath and stirred for 10 min before the dropwise addition of benzoyl chloride (0.21 g, 1.0 equiv). The flask was stirred for 10 min before being removed from the ice bath and allowed to warm to room temperature. The flask was stirred overnight (16 h), upon which time the reaction was deemed complete by TLC. The reaction mixture was washed with 1 M HCl (2 × 10 mL) and then brine and dried over anhydrous Na_2SO_4, and the solvent was evaporated in vacuo and purified by flash chromatography to get the products **1-Bz**.

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J. Org. Chem. 2021, 86, 6800−6812

General Procedure (C) for the Synthesis of Products 2 from Electron-Poor Arene-Substituted ACBs 1. A solution of the iodosylbenzene polymer ($(PhIO)_n$, 66.0 mg, 0.3 mmol, 1.5 equiv) and 0.2 mmol (1.0 equiv) corresponding substrates **1** in toluene (1 mL) in a 10 mL polyethylene tube under an ambient atmosphere was stirred in an ice bath for 5 min, and then, Py·HF (65% hydrogen fluoride by weight, 130 μL, 24.0 equiv hydrogen fluoride) was added carefully (CAUTION, generation of HF!). The reaction was allowed to stir at 0 °C for 5 min after complete consumption of the starting materials as monitored by TLC analysis. The reaction mixture was quenched by the addition of a saturated aqueous solution of NaCl. The biphasic mixture was then extracted with EtOAc, and the combined organic layers were dried over Na_2SO_4 and concentrated under reduced pressure. The residue was purified by column chromatography on silica with an appropriate eluent to afford the pure products **2**.

General Procedure (D) for the Synthesis of Products 2 from Benzoyl-Protected Electron-Rich Arene-Substituted ACBs 1-Bz. To a stirred solution of the iodosylbenzene polymer ($(PhIO)_n$, 88.0 mg, 0.4 mmol, 2.0 equiv) in toluene (1 mL) in a 10 mL polyethylene tube under an ambient atmosphere were added Tf_2O (5 μL, 15 mol %) and Py·HF (65% hydrogen fluoride by weight, 130 μL, 24 equiv hydrogen fluoride) carefully (CAUTION, generation of HF!). The reaction was allowed to stir at room temperature for 5 min; then, 1.0 equiv of corresponding substrates **1-Bz** was added. The reaction mixture was stirred at room temperature until the complete consumption of the starting materials as monitored by TLC analysis (30 min). The reaction mixture was quenched by the addition of a saturated aqueous solution of NaCl and extracted with EtOAc, and the combined organic layers were concentrated under reduced pressure. The residue was added to 3 mL of MeOH and 5 equiv of K_2CO_3 (70 mg), and the mixture was allowed to stir at room temperature for 15 min. Then, MeOH was removed under reduced pressure. The residue was extracted with water and EtOAc, and the combined organic layers were concentrated under reduced pressure. The residue was purified by column chromatography on silica with an appropriate eluent to afford the pure products **2**.

*Ethyl (E)-4-((2-Hydroxycyclobutylidene)methyl)-benzoate (**1a**).* Following the general procedure A, product **1a** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (500 MHz, chloroform-*d*): δ 7.99 (d, *J* = 7.7 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 6.47 (s, 1H), 4.92−4.81 (m, 1H), 4.37 (q, *J* = 7.1 Hz, 2H), 2.86−2.75 (m, 1H), 2.75−2.64 (m, 1H), 2.60−2.49 (m, 1H), 2.06−1.92 (m, 2H), 1.39 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 166.6, 151.1, 141.3, 129.7, 128.3, 127.5, 119.3, 72.0, 60.9, 31.6, 25.3, 14.3. HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{14}H_{17}O_3$, 233.1172; found, 233.1153.

*Methyl (E)-4-((2-Hydroxycyclobutylidene)methyl)-benzoate (**1b**).* Following the general procedure A, product **1b** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.98 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.3 Hz, 2H), 6.52−6.41 (m, 1H), 4.86 (s, 1H), 3.90 (s, 3H), 2.84−2.75 (m, 1H), 2.75−2.64 (m, 1H), 2.58−2.47 (m, 1H), 2.17−1.94 (m, 2H). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 167.0, 151.1, 141.4, 129.8, 128.0, 127.6, 119.3, 72.1, 52.1, 31.7, 25.3. HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{13}H_{15}O_3$, 219.1016; found, 219.1010.

*(E)-2-(4-(Trifluoromethyl)benzylidene)cyclobutan-1-ol (**1c**).* Following the general procedure A, product **1c** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.55 (d, *J* = 7.9 Hz, 2H), 7.33 (d, *J* = 7.9 Hz, 2H), 6.46 (s, 1H), 4.90−4.81 (m, 1H), 2.81−2.73 (m, 1H), 2.71−2.64 (m, 1H), 2.56−2.48 (m, 1H), 2.04−1.93 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 150.8, 140.2, 128.4 (q, *J* = 32.6 Hz), 127.8, 125.3 (q, *J* = 3.7 Hz), 124.2 (q, *J* = 272 Hz), 118.9, 72.1, 31.7, 25.2. HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{12}H_{12}F_3O$, 229.0835; found, 229.0821.

*(E)-4-((2-Hydroxycyclobutylidene)methyl)benzo-nitrile (**1d**).* Following the general procedure A, product **1d** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (500 MHz, chloroform-*d*): δ 7.57 (d, *J* = 7.9 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 6.44 (s, 1H), 4.93−4.81 (m, 1H), 2.80−2.72 (m, 1H), 2.71−2.61 (m, 1H), 2.58−2.48 (m, 1H), 2.32−2.24 (m, 1H), 2.05−1.95 (m, 1H). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 152.5, 141.4, 132.2, 128.1, 119.1, 118.7, 109.7, 72.0, 31.6, 25.3. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{11}NONa$, 208.0733; found, 208.0737.

*(E)-3-((2-Hydroxycyclobutylidene)methyl)benzo-nitrile (**1j**).* Following the general procedure A, product **1j** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.57−7.39 (m, 4H), 6.45−6.36 (m, 1H), 4.94−4.80 (m, 1H), 2.81−2.65 (m, 2H), 2.60−2.50 (m, 1H), 2.04−1.96 (m, 2H). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 151.0, 138.0, 132.0, 130.9, 129.9, 129.2, 118.9, 118.03, 112.5, 71.9, 31.7, 25.1. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{11}NONa$, 208.0733; found, 208.0727.

*(E)-2-(3-(Trifluoromethyl)benzylidene)cyclobutan-1-ol (**1k**).* Following the general procedure A, product **1k** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.49 (s, 1H), 7.45−7.41 (m, 3H), 6.51−6.40 (m, 1H), 4.93−4.79 (m, 1H), 2.85−2.63 (m, 2H), 2.60−2.48 (m, 1H), 2.08−1.91 (m, 2H). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 150.0, 137.5, 130.7, 128.9, 124.3 (q, *J* = 3.7 Hz), 123.70 (q, *J* = 271 Hz), 123.2 (q, *J* = 3.6 Hz), 118.8, 72.0, 31.7, 25.1. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{11}F_3ONa$, 251.0654; found, 251.0650.

*(E)-2-(2,4-Dichlorobenzylidene)cyclobutan-1-ol (**1m**).* Following the general procedure A, product **1m** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.39 (d, *J* = 2.1 Hz, 1H), 7.25−7.16 (m, 2H), 6.77−6.66 (m, 1H), 4.92−4.77 (m, 1H), 2.68−2.59 (m, 2H), 2.56−2.48 (m, 1H), 2.03−1.91 (m, 2H). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 151.0, 133.6, 132.9, 132.7, 129.5, 129.3, 126.8, 115.2, 72.1, 31.6, 24.8. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}Cl_2ONa$, 251.0001; found, 251.0003.

*(E)-2-(Pyridin-3-ylmethylene)cyclobutan-1-ol (**1n**).* Following the general procedure A, product **1n** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 2:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 8.52−8.32 (m, 2H), 7.57−7.47 (m, 1H), 7.23 (dd, J = 7.9, 4.8 Hz, 1H), 6.44−6.34 (m, 1H), 4.92−4.80 (m, 1H), 3.34 (s, 1H), 2.77−2.59 (m, 2H), 2.57−2.42 (m, 1H), 2.05−1.92 (m, 1H). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 151.1, 148.9, 147.2, 134.5, 132.7, 123.4, 116.3, 71.9, 31.7, 25.1. HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{10}H_{12}NO$, 162.0913; found, 162.0904.

*(E)-2-([1,1′-Biphenyl]-4-ylmethylene)cyclobutan-1-ol (**1u**).* Following the general procedure A, product **1u** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 10:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 7.66−7.53 (m, 4H), 7.48−7.41 (m, 2H), 7.38−7.31 (m, 3H), 6.48 (s, 1H), 4.94−4.82 (m, 1H), 2.90−2.79 (m, 1H), 2.76−2.65 (m, 1H), 2.59−2.49 (m, 1H), 2.11−1.92 (m, 2H). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 148.1, 140.7, 139.4, 135.9, 128.8, 128.2, 127.3, 127.1, 126.9, 119.7, 72.3, 32.0, 25.3. HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{17}H_{17}O$, 237.1274; found, 237.1272.

*(E)-2-(4-Methylbenzylidene)cyclobutyl Benzoate (**1o-Bz**).* Following the general procedure B, product **1o-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v) ^{1}H NMR (500 MHz, chloroform-*d*): δ 8.15−8.07 (m, 2H), 7.62−7.53 (m, 1H), 7.50−7.41 (m, 2H), 7.23−7.09 (m, 4H), 6.51−6.43 (m, 1H), 5.98−5.89 (m, 1H), 3.04−2.93 (m, 1H), 2.90−2.80 (m, 1H), 2.71−2.62 (m, 1H), 2.34 (m, 4H). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 165.2, 139.4, 135.7, 132.8, 132.0, 129.1, 128.7, 128.1, 127.3, 126.8, 122.3, 72.2, 27.1, 25.5, 20.2. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{19}H_{18}O_2Na$, 301.1199; found, 301.1176.

*(E)-2-(3-Methylbenzylidene)cyclobutyl Benzoate (**1p-Bz**).* Following the general procedure B, product **1p-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^{1}H NMR (400 MHz, chloroform-*d*): δ 8.16 (d, *J* = 7.8 Hz, 2H), 7.61 (t, *J* = 7.4 Hz, 1H), 7.54−7.46 (m, 3H), 7.28−7.23 (m,

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J. Org. Chem. 2021, 86, 6800−6812

1H), 7.16−7.11 (m, 3H), 7.08 (d, J = 7.6 Hz, 1H), 6.52 (s, 1H), 6.05−5.92 (m, 1H), 3.10−2.98 (m, 1H), 2.96−2.84 (m, 1H), 2.76−2.65 (m, 1H), 2.42−2.32 (m, 4H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.2, 141.4, 138.0, 136.6, 133.0, 130.2, 129.8, 128.7, 128.4, 128.3, 127.8, 124.9, 123.5, 73.2, 28.1, 26.7, 21.5. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{19}H_{18}O_2Na$, 301.1199; found, 301.1175.

*(E)-2-(2-Methylbenzylidene)cyclobutyl Benzoate (**1q-Bz**).* Following the general procedure B, product **1q-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (500 MHz, chloroform-d): δ 8.13 (d, J = 7.7 Hz, 2H), 7.59 (t, J = 7.4 Hz, 1H), 7.48 (t, J = 7.7 Hz, 2H), 7.29 (d, J = 7.7 Hz, 1H), 7.17 (m, 3H), 6.73−6.66 (m, 1H), 6.01−5.90 (m, 1H), 2.96−2.86 (m, 1H), 2.87−2.77 (m, 1H), 2.67 (m, 1H), 2.34 (s, 3H), 2.32−2.25 (m, 1H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.2, 141.8, 135.9, 135.0, 133.1, 130.3, 130.2, 129.7, 128.4, 127.4, 127.1, 125.8, 120.7, 73.3, 28.2, 26.3, 19.9. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{19}H_{18}O_2Na$, 301.1199; found, 301.1182.

*(E)-2-(4-Isopropylbenzylidene)cyclobutyl Benzoate (**1r-Bz**).* Following the general procedure B, product **1r-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (500 MHz, chloroform-d): δ 8.11 (d, J = 7.7 Hz, 1H), 7.58 (t, J = 7.4 Hz, 1H), 7.46 (t, J = 7.6 Hz, 1H), 7.21 (q, J = 8.1 Hz, 3H), 6.47 (s, 1H), 5.97−5.89 (m, 1H), 3.05−2.95 (m, 1H), 2.93−2.81 (m, 2H), 2.72−2.62 (m, 1H), 2.37−2.27 (m, 1H), 1.24 (d, J = 6.9 Hz, 6H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.2, 147.8, 140.6, 134.3, 133.0, 130.2, 129.8, 128.4, 127.9, 126.6, 123.3, 73.3, 33.9, 28.2, 26.6, 22.0. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{21}H_{22}O_2Na$, 329.1512; found, 329.1485.

*(E)-2-(4-(tert-Butyl)benzylidene)cyclobutyl Benzoate (**1s-Bz**).* Following the general procedure B, product **1s-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (400 MHz, chloroform-d): δ 8.18−8.12 (m, 2H), 7.64−7.57 (m, 1H), 7.49 (dd, J = 8.4, 7.1 Hz, 2H), 7.41−7.36 (m, 2H), 7.27 (d, J = 8.4 Hz, 2H), 6.51 (q, J = 2.5 Hz, 1H), 6.02−5.93 (m, 1H), 3.09−2.98 (m, 1H), 2.95−2.84 (m, 1H), 2.75−2.65 (m, 1H), 2.40−2.30 (m, 1H), 1.35 (s, 9H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.2, 150.0, 140.7, 133.9, 133.0, 130.2, 129.7, 128.4, 127.6, 125.4, 123.2, 73.3, 34.6, 31.3, 28.1, 26.6. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{22}H_{24}O_2Na$, 343.1669; found, 343.1654.

*(E)-2-Benzylidenecyclobutyl Benzoate (**1t-Bz**).* Following the general procedure B, product **1t-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (400 MHz, chloroform-d): δ 8.14−8.09 (m, 2H), 7.61−7.54 (m, 1H), 7.49−7.42 (m, 2H), 7.36−7.26 (m, 4H), 7.24−7.17 (m, 1H), 6.54−6.46 (m, 1H), 5.98−5.90 (m, 1H), 3.05−2.94 (m, 1H), 2.91−2.79 (m, 1H), 2.71−2.60 (m, 1H), 2.39−2.28 (m, 1H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.2, 141.7, 136.7, 133.1, 130.2, 129.8, 128.5, 128.4, 127.9, 127.0, 123.4, 73.2, 28.2, 26.7. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{18}H_{16}O_2Na$, 287.1043; found, 287.1033.

*(E)-2-([1,1′-Biphenyl]-4-ylmethylene)cyclobutyl Benzoate (**1u-Bz**).* Following the general procedure B, product **1u-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (400 MHz, chloroform-d): δ 8.18−8.08 (m, 2H), 7.65−7.55 (m, 5H), 7.46 (dt, J = 14.8, 7.6 Hz, 4H), 7.39−7.30 (m, 3H), 6.54 (q, J = 2.5 Hz, 1H), 6.02−5.94 (m, 1H), 3.13−2.99 (m, 1H), 2.98−2.85 (m, 1H), 2.77−2.64 (m, 1H), 2.45−2.30 (m, 1H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 165.2, 140.8, 139.6, 138.6, 134.7, 133.5, 132.0, 129.5, 129.1, 128.7, 127.8, 127.7, 127.4, 127.3, 126.2, 126.1, 125.9, 121.9, 72.2, 27.1, 25.7. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{24}H_{20}O_2Na$, 363.1356; found, 363.1360.

*(E)-2-(Naphthalen-1-ylmethylene)cyclobutyl Benzoate (**1v-Bz**).* Following the general procedure B, product **1v-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (500 MHz, chloroform-d): δ 8.20 (d, J = 7.8 Hz, 2H), 8.11 (d, J = 8.0 Hz, 1H), 7.88−7.84 (m, 1H), 7.81−7.75 (m, 1H), 7.63 (t, J = 7.4 Hz, 1H), 7.55−7.45 (m, 6H), 7.26−7.23 (m, 1H), 2.92−2.80 (m, 2H), 2.75−2.65 (m, 1H), 2.40−2.30 (m, 1H). $^{13}C\{^1H\}$ NMR (126 MHz, chloroform-d): δ 166.3, 143.4, 133.7, 133.1, 132.8, 131.4, 130.2, 129.8, 128.6, 128.5, 127.6, 126.0, 125.8, 125.4, 125.3, 124.0, 119.8, 73.1, 28.1, 26.2. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{22}H_{18}O_2Na$, 337.1199; found, 337.1183.

*(E)-2-(Thiophen-2-ylmethylene)cyclobutyl Benzoate (**1x-Bz**).* Following the general procedure B, product **1x-Bz** was obtained as a white solid after column chromatography (eluent = petroleum ether/EtOAc 150:1 v/v). ^1H NMR (400 MHz, chloroform-d): δ 8.05−7.98 (m, 2H), 7.52−7.45 (m, 1H), 7.37 (dd, J = 8.4, 7.0 Hz, 2H), 7.19−7.13 (m, 1H), 6.91 (dd, J = 5.1, 3.6 Hz, 1H), 6.86 (d, J = 3.5 Hz, 1H), 6.71−6.64 (m, 1H), 5.89−5.81 (m, 1H), 2.98−2.85 (m, 1H), 2.72−2.64 (m, 1H), 2.63−2.53 (m, 1H), 2.31−2.21 (m, 1H). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 166.3, 140.5, 140.1, 133.1, 130.1, 129.8, 128.4, 127.0, 126.2, 125.4, 117.8, 72.9, 27.3, 26.3. HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{16}H_{14}O_2SNa$, 293.0607; found, 293.0591.

*Ethyl 4-(Fluoro(1-formylcyclopropyl)methyl)-benzoate (**2a**).* Following the general procedure C, product **2a** was obtained in 68% yield (33.9 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 20:1 v/v), (PE/EA = 8/1, $R_F \approx 0.40$). ^1H NMR (400 MHz, chloroform-d): δ 9.07 (d, J = 1.8 Hz, 1H), 8.06 (d, J = 8.0 Hz, 2H), 7.41 (d, J = 8.0 Hz, 2H), 6.11 (d, J = 46.7 Hz, 1H), 4.39 (q, J = 7.1 Hz, 2H), 1.43−1.33 (m, 5H), 1.31−1.23 (m, 1H), 1.02−0.94 (m, 1H). ^{19}F NMR (376 MHz, chloroform-d): δ −182.01 (d, J = 46.5 Hz). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 198.9, 166.1, 142.0 (d, J = 21.9 Hz), 129.7, 129.4, 125.7 (d, J = 8.0 Hz), 90.7 (d, J = 176.6 Hz), 61.2, 36.0 (d, J = 25.7 Hz), 14.3, 13.1 (d, J = 2.9 Hz), 11.1 (d, J = 5.4 Hz). **HRMS** (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{14}H_{15}FO_3Na$, 273.0897; found, 273.0888.

*Methyl 4-(Fluoro(1-formylcyclopropyl)methyl)-benzoate (**2b**).* Following the general procedure C, product **2b** was obtained in 65% yield (30.2 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 25:1 v/v), (PE/EA = 8/1, $R_F \approx$ 0.30). ^1H NMR (400 MHz, chloroform-d): δ 9.06 (d, J = 1.8 Hz, 1H), 8.09−8.01 (m, 2H), 7.47−7.38 (m, 2H), 6.10 (d, J = 46.7 Hz, 1H), 3.93 (s, 3H), 1.41−1.34 (m, 2H), 1.31−1.25 (m, 1H), 1.03−0.95 (m, 1H). ^{19}F NMR (376 MHz, chloroform-d): δ −182.15 (d, J = 47.6 Hz). $^{13}C\{^1H\}$ NMR (101 MHz, chloroform-d): δ 198.9, 166.6, 142.2 (d, J = 22.0 Hz), 130.3, 129.7, 125.8, 125.7, 90.7 (d, J = 176.3 Hz), 52.3, 36.0 (d, J = 25.8 Hz), 13.1 (d, J = 2.8 Hz), 11.2 (d, J = 5.3 Hz). HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{13}H_{13}FO_3Na$, 259.0741; found, 259.0734.

*1-(Fluoro(4-(trifluoromethyl)phenyl)methyl)-cyclopropane-1-carbaldehyde (**2c**).* Following the general procedure C, product **2c** was obtained in 66% yield (32.6 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 80:1 v/v), (PE/EA = 20/1, $R_F \approx 0.35$). ^1H NMR (400 MHz, chloroform-d): δ 9.01 (d, J = 2.1 Hz, 1H), 7.65 (d, J = 8.1 Hz, 2H), 7.48 (d, J = 8.1 Hz, 2H), 6.10 (d, J = 46.5 Hz, 1H), 1.42−1.35 (m, 2H), 1.32−1.28 (m, 1H), 1.07−1.00 (m, 1H). ^{19}F NMR (376 MHz, chloroform-d): δ −62.72, −183.15 (d, J = 47.4 Hz). $^{13}C\{^1H\}$ NMR (126 MHz, chloroform-d): δ 198.7 (d, J = 1.2 Hz), 141.3 (d, J = 22.2 Hz), 130.7 (q, J = 32.4 Hz), 126.2, 126.2, 125.4 (q, J = 3.9 Hz), 123.4 (q, J = 272 Hz), 90.4 (d, J = 176.6 Hz), 36.1 (d, J = 25.5 Hz), 12.7 (d, J = 2.6 Hz), 11.0 (d, J = 5.6 Hz). HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{12}H_{10}F_4ONa$, 269.0560; found, 269.0564.

*4-(Fluoro(1-formylcyclopropyl)methyl)benzonitrile (**2d**).* Following the general procedure C, product **2d** was obtained in 68% yield (27.7 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 15:1 v/v), (PE/EA = 8/1, $R_F \approx 0.26$). ^1H NMR (400 MHz, chloroform-d): δ 8.92 (d, J = 2.4 Hz, 1H), 7.67 (d, J = 8.1 Hz, 2H), 7.48 (d, J = 8.2 Hz, 2H), 6.05 (d, J = 46.3 Hz, 1H), 1.43−1.37 (m, 2H), 1.33−1.27 (m, 1H), 1.08−1.01 (m, 1H). ^{19}F NMR (376 MHz, chloroform-d): δ −184.74 (d, J = 47.3 Hz). $^{13}C\{^1H\}$ NMR (126 MHz, chloroform-d): δ 198.4 (d, J = 2.2 Hz), 142.7 (d, J = 22.3 Hz), 132.2, 126.5 (d, J = 8.1 Hz), 118.3, 112.5 (d, J = 1.6 Hz), 90.1 (d, J = 177.5 Hz), 36.1 (d, J = 25.1 Hz), 12.4 (d, J = 2.3 Hz), 11.0 (d, J = 5.9 Hz). HRMS (ESI-TOF) m/z: $[M + Na]^+$ calcd for $C_{12}H_{10}FNONa$, 226.0639; found, 226.0636.

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J. Org. Chem. 2021, 86, 6800−6812

*1-(Fluoro(4-fluorophenyl)methyl)cyclopropane-1-carbaldehyde (**2e**).* Following the general procedure C, product **2e** was obtained in 42% yield (16.5 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 90:1 v/v), (PE/EA = 20/1, $R_F \approx 0.35$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.08 (d, *J* = 2.1 Hz, 1H), 7.37−7.29 (m, 2H), 7.11−7.02 (m, 2H), 6.02 (d, *J* = 46.4 Hz, 1H), 1.38−1.31 (m, 2H), 1.30−1.24 (m, 1H), 1.05−0.97 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −112.94 to −113.35 (m), −179.60 (d, *J* = 47.3 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 199.2 (d, *J* = 1.8 Hz), 162.7 (dd, *J* = 247.5, 1.8 Hz), 133.0, 127.8 (t, *J* = 7.8 Hz), 115.4 (d, *J* = 21.8 Hz), 90.7 (d, *J* = 174.9 Hz), 36.0 (d, *J* = 26.1 Hz), 12.9 (d, *J* = 2.7 Hz), 10.9 (d, *J* = 5.3 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}F_2ONa$, 219.0592; found, 219.0594.

*1-((4-Chlorophenyl)fluoromethyl)cyclopropane-1-carbaldehyde (**2f**).* Following the general procedure C, product **2f** was obtained in 48% yield (20.4 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 90:1 v/v), (PE/EA = 20/1, $R_F \approx 0.35$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.06 (d, *J* = 2.0 Hz, 1H), 7.36 (d, *J* = 8.5 Hz, 2H), 7.28 (d, *J* = 8.5 Hz, 2H), 6.02 (d, *J* = 46.5 Hz, 1H), 1.38−1.30 (m, 2H), 1.30−1.23 (m, 1H), 1.05−0.97 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −181.07 (d, *J* = 47.4 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.1, 135.7 (d, *J* = 22.1 Hz), 134.5 (d, *J* = 1.4 Hz), 128.7, 127.3 (d, *J* = 7.9 Hz), 90.6 (d, *J* = 175.4 Hz), 36.0 (d, *J* = 26.0 Hz), 12.9 (d, *J* = 2.8 Hz), 11.0 (d, *J* = 5.3 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}ClFONa$, 235.0296; found, 235.0298.

*1-((4-Bromophenyl)fluoromethyl)cyclopropane-1-carbaldehyde (**2g**).* Following the general procedure C, product **2g** was obtained in 49% yield (25.4 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 80:1 v/v), (PE/EA = 20/1, $R_F \approx 0.31$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.05 (d, *J* = 2.0 Hz, 1H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.22 (d, *J* = 8.4 Hz, 2H), 6.00 (d, *J* = 46.5 Hz, 1H), 1.38−1.31 (m, 2H), 1.30−1.24 (m, 1H), 1.04−0.97 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −181.42 (d, *J* = 46.3 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.0, 136.3 (d, *J* = 22.4 Hz), 131.6, 127.6 (d, *J* = 7.8 Hz), 122.6, 90.6 (d, *J* = 175.5 Hz), 35.9 (d, *J* = 26.2 Hz), 12.9 (d, *J* = 2.8 Hz), 11.0 (d, *J* = 5.2 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}BrFONa$, 278.9791; found, 278.9794.

*1-(Fluoro(3-fluorophenyl)methyl)cyclopropane-1-carbaldehyde (**2h**).* Following the general procedure C, product **2h** was obtained in 65% yield (25.4 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 90:1 v/v), (PE/EA = 20/1, $R_F \approx 0.33$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.08 (d, *J* = 1.8 Hz, 1H), 7.35 (td, *J* = 7.9, 5.7 Hz, 1H), 7.13−7.01 (m, 3H), 6.03 (d, *J* = 46.6 Hz, 1H), 1.39−1.34 (m, 2H), 1.32−1.25 (m, 1H), 1.05−0.99 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −111.96 to −112.29 (m), −180.92 (d, *J* = 47.5 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 199.0 (d, *J* = 1.6 Hz), 162.7 (d, *J* = 246.4 Hz), 139.8 (dd, *J* = 22.4, 7.2 Hz), 130.1 (d, *J* = 8.2 Hz), 121.5 (dd, *J* = 7.7, 3.0 Hz), 115.5 (d, *J* = 21.0 Hz), 113.0 (dd, *J* = 22.8, 8.5 Hz), 90.6 (dd, *J* = 176.2, 1.9 Hz), 36.0 (d, *J* = 25.9 Hz), 13.1 (d, *J* = 2.7 Hz), 11.2 (d, *J* = 5.5 Hz). HRMS (ESI-TOF) *m*/*z*: [M + K]$^+$ calcd for $C_{11}H_{10}F_2OK$, 235.0331; found, 235.0328.

*1-((3-Bromophenyl)fluoromethyl)cyclopropane-1-carbaldehyde (**2i**).* Following the general procedure C, product **2i** was obtained in 69% yield (35.5 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx 0.35$). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.07 (d, *J* = 2.0 Hz, 1H), 7.53−7.45 (m, 2H), 7.28−7.23 (m, 2H), 6.00 (d, *J* = 46.5 Hz, 1H), 1.40−1.33 (m, 2H), 1.31−1.27 (m, 1H), 1.06−1.00 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −181.53 (dd, *J* = 46.3, 2.9 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 198.9 (d, *J* = 1.7 Hz), 139.6 (d, *J* = 22.2 Hz), 131.6, 130.0, 128.9 (d, *J* = 8.2 Hz), 124.5 (d, *J* = 7.5 Hz), 122.6, 90.4 (d, *J* = 176.4 Hz), 36.0 (d, *J* = 25.8 Hz), 13.0 (d, *J* = 2.5 Hz), 11.1 (d, *J* = 5.5 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}BrFONa$, 278.9791; found, 278.9784.

*3-(Fluoro(1-formylcyclopropyl)methyl)benzonitrile (**2j**).* Following the general procedure C, product **2j** was obtained in 69% yield (28.1 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 25:1 v/v), (PE/EA = 8/1, $R_F \approx 0.2$). ^{1}H NMR (500 MHz, chloroform-*d*): δ 8.93 (d, *J* = 2.6 Hz, 1H), 7.64 (dd, *J* = 18.6, 9.7 Hz, 3H), 7.51 (t, *J* = 7.8 Hz, 1H), 6.02 (d, *J* = 46.1 Hz, 1H), 1.44−1.37 (m, 2H), 1.35−1.31 (m, 1H), 1.13−1.08 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −184.76 (d, *J* = 46.2 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 198.4 (d, *J* = 2.5 Hz), 139.2 (d, *J* = 22.7 Hz), 132.2, 130.3 (d, *J* = 7.6 Hz), 129.4 (d, *J* = 8.3 Hz), 129.3, 118.4, 112.8, 89.8 (d, *J* = 177.3 Hz), 36.1 (d, *J* = 25.0 Hz), 12.1 (d, *J* = 2.3 Hz), 10.9 (d, *J* = 5.9 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{10}FNONa$, 226.0639; found, 226.0647.

*1-(Fluoro(3-(trifluoromethyl)phenyl)methyl)cyclopropane-1-carbaldehyde (**2k**).* Following the general procedure C, product **2k** was obtained in 72% yield (35.5 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 90:1 v/v), (PE/EA = 20/1, $R_F \approx 0.32$). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.02 (d, *J* = 1.7 Hz, 1H), 7.61 (m, 2H), 7.53 (m, 2H), 6.09 (d, *J* = 46.3 Hz, 1H), 1.42−1.35 (m, 2H), 1.28−1.24 (m, 1H), 1.07−1.00 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −62.72, −182.76 (d, *J* = 47.0 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 198.7, 138.5 (d, *J* = 22.7 Hz), 129.5 (q, *J* = 271 Hz), 129.3 (d, *J* = 7.5 Hz), 129.0, 125.4 (q, *J* = 3.7 Hz), 122.6 (q, *J* = 5.1 Hz), 90.4 (d, *J* = 176.6 Hz), 36.0 (d, *J* = 25.7 Hz), 12.7 (d, *J* = 2.7 Hz), 11.0 (d, *J* = 5.7 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{10}F_4ONa$, 269.0560; found, 269.0553.

*1-((2-Chlorophenyl)fluoromethyl)cyclopropane-1-carbaldehyde (**2l**).* Following the general procedure C, product **2l** was obtained in 57% yield (24.1 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 110:1 v/v), (PE/EA = 20/1, $R_F \approx 0.4$). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.15 (s, 1H), 7.46−7.41 (m, 1H), 7.39−7.35 (m, 1H), 7.32−7.28 (m, 2H), 6.71 (d, *J* = 47.2 Hz, 1H), 1.32−1.27 (m, 2H), 1.27−1.21 (m, 1H), 0.68−0.60 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.44 (dd, *J* = 47.6, 6.8 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 199.0, 134.1 (d, *J* = 23.0 Hz), 131.9 (d, *J* = 6.1 Hz), 129.6 (d, *J* = 35.9 Hz), 127.2−126.8 (m), 87.9 (d, *J* = 174.0 Hz), 35.0 (d, *J* = 28.0 Hz), 14.4 (d, *J* = 4.4 Hz), 10.2 (d, *J* = 4.6 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{10}ClFONa$, 235.0296; found, 235.0286.

*1-((2,4-Dichlorophenyl)fluoromethyl)cyclopropane-1-carbaldehyde (**2m**).* Following the general procedure C, product **2m** was obtained in 53% yield (26.4 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 120:1 v/v), (PE/EA = 20/1, $R_F \approx 0.47$). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.07 (s, 1H), 7.42−7.34 (m, 2H), 7.33−7.28 (m, 1H), 6.64 (d, *J* = 46.9 Hz, 1H), 1.34−1.28 (m, 3H), 1.24−1.20 (m, 1H), 0.71−0.59 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.50 (d, *J* = 48.1 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 198.5, 135.1, 132.8 (d, *J* = 22.8 Hz), 132.6 (d, *J* = 5.9 Hz), 129.35, 128.1 (d, *J* = 10.3 Hz), 127.3, 87.5 (d, *J* = 175.2 Hz), 34.9 (d, *J* = 28.0 Hz), 14.1 (d, *J* = 4.4 Hz), 10.0 (d, *J* = 4.9 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_9Cl_2FONa$, 268.9907; found, 268.9901.

*1-(Fluoro(p-tolyl)methyl)cyclopropane-1-carbaldehyde (**2o**).* Following the general procedure D, product **2o** was obtained in 56% yield (20.6 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 90:1 v/v), (PE/EA = 20/1, $R_F \approx 0.3$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.18 (d, *J* = 1.5 Hz, 1H), 7.20 (q, *J* = 8.2 Hz, 4H), 6.01 (d, *J* = 46.7 Hz, 1H), 2.35 (s, 3H), 1.36−1.29 (m, 2H), 1.28−1.22 (m, 1H), 1.01−0.94 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.87 (d, *J* = 47.5 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.7, 138.4, 134.1 (d, *J* = 21.8 Hz), 129.1, 125.9 (d, *J* = 7.3 Hz), 91.5 (d, *J* = 173.9 Hz), 35.9 (d, *J* = 26.4 Hz), 21.2, 13.5 (d, *J* = 3.0 Hz), 11.2 (d, *J* = 4.7 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{13}FONa$, 215.0843; found, 215.0848.

*1-(Fluoro(m-tolyl)methyl)cyclopropane-1-carbaldehyde (**2p**).* Following the general procedure D, product **2p** was obtained in 45% yield (17.7 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx 0.35$). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.19 (d, *J* = 1.5 Hz, 1H), 7.31−7.22 (m, 1H), 7.16−7.09 (m, 3H), 6.01 (d, *J* = 46.8 Hz,

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J. Org. Chem. 2021, 86, 6800−6812

1H), 2.36 (s, 3H), 1.37−1.30 (m, 2H), 1.29−1.22 (m, 1H), 1.02−0.94 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −179.24 (d, *J* = 47.5 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.7, 138.2, 137.0 (d, *J* = 21.4 Hz), 129.3, 128.3, 126.5 (d, *J* = 7.4 Hz), 122.9 (d, *J* = 7.5 Hz), 91.6 (d, *J* = 174.2 Hz), 35.9 (d, *J* = 26.5 Hz), 21.5, 13.7 (d, *J* = 2.9 Hz), 11.4 (d, *J* = 5.1 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{13}FONa$, 215.0843; found, 215.0833.

*1-(Fluoro(o-tolyl)methyl)cyclopropane-1-carbaldehyde (**2q**).* Following the general procedure D, product **2q** was obtained in 45% yield (17.3 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.33). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.09 (s, 1H), 7.33 (dd, *J* = 6.7, 2.4 Hz, 1H), 7.25−7.20 (m, 2H), 7.18−7.13 (m, 1H), 6.59 (d, *J* = 47.2 Hz, 1H), 2.23 (s, 3H), 1.33−1.27 (m, 2H), 1.27−1.21 (m, 1H), 0.59−0.53 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −177.74 (dd, *J* = 47.2, 5.1 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.5, 134.7 (d, *J* = 5.6 Hz), 134.3 (d, *J* = 20.0 Hz), 130.3, 128.4, 126.0, 125.1 (d, *J* = 10.3 Hz), 87.6 (d, *J* = 172.4 Hz), 35.2 (d, *J* = 28.0 Hz), 19.0, 13.8 (d, *J* = 4.3 Hz), 9.8 (d, *J* = 4.5 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{12}H_{13}FONa$, 215.0843; found, 215.0844.

*1-(Fluoro(4-isopropylphenyl)methyl)cyclopropane-1-carbaldehyde (**2r**).* Following the general procedure D, product **2r** was obtained in 52% yield (23.0 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.45). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.21 (d, *J* = 1.5 Hz, 1H), 7.24 (d, *J* = 3.3 Hz, 4H), 6.00 (d, *J* = 46.7 Hz, 1H), 2.91 (p, *J* = 6.9 Hz, 1H), 1.39−1.30 (m, 2H), 1.30−1.26 (m, 1H), 1.25 (d, *J* = 6.9 Hz, 6H), 1.04−0.96 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.71 (d, *J* = 47.5 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 199.8, 149.3, 134.4 (d, *J* = 21.8 Hz), 126.5, 126.0 (d, *J* = 7.3 Hz), 91.7 (d, *J* = 174.0 Hz), 35.9 (d, *J* = 26.6 Hz), 33.9, 23.9, 13.6 (d, *J* = 2.8 Hz), 11.3 (d, *J* = 5.0 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{14}H_{17}FONa$, 243.1156; found, 243.1161.

*1-((4-(tert-Butyl)phenyl)fluoromethyl)-cyclopropane-1-carbaldehyde (**2s**).* Following the general procedure D, product **2s** was obtained in 55% yield (25.8 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 110:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.38). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.21 (d, *J* = 1.5 Hz, 1H), 7.39 (d, *J* = 8.3 Hz, 2H), 7.26 (d, *J* = 8.3 Hz, 2H), 6.00 (d, *J* = 46.7 Hz, 1H), 1.32 (m, 11H), 1.29−1.21 (m, 1H), 1.05−0.97 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.89 (d, *J* = 47.4 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.8, 151.6, 134.0 (d, *J* = 22.0 Hz), 125.7, 125.7, 125.4, 91.7 (d, *J* = 173.9 Hz), 35.9 (d, *J* = 26.4 Hz), 34.6, 31.3, 13.6 (d, *J* = 2.6 Hz), 11.4 (d, *J* = 5.1 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{15}H_{19}FONa$, 257.1312; found, 257.1297.

*1-(Fluoro(phenyl)methyl)cyclopropane-1-carbaldehyde (**2t**).* Following the general procedure D, product **2t** was obtained in 48% yield (17.1 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.3). ^{1}H NMR (400 MHz, chloroform-*d*): δ 9.09 (d, *J* = 1.5 Hz, 1H), 7.34−7.22 (m, 5H), 5.98 (d, *J* = 46.8 Hz, 1H), 1.29−1.24 (m, 2H), 1.21−1.16 (m, 1H), 0.93−0.87 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −179.81 (d, *J* = 47.2 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.6, 137.1 (d, *J* = 21.9 Hz), 128.5 (d, *J* = 1.5 Hz), 128.4, 125.9 (d, *J* = 7.7 Hz), 91.5 (d, *J* = 174.7 Hz), 35.9 (d, *J* = 26.4 Hz), 13.5 (d, *J* = 2.9 Hz), 11.2 (d, *J* = 5.2 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{11}H_{11}FONa$, 201.0686; found, 201.0689.

*1-([1,1′-Biphenyl]-4-ylfluoromethyl)cyclopropane-1-carbaldehyde (**2u**).* Following the general procedure D, product **2u** was obtained in 54% yield (27.5 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 100:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.32). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.19 (s, 1H), 7.59 (t, *J* = 8.7 Hz, 4H), 7.48−7.38 (m, 4H), 7.36 (t, *J* = 7.4 Hz, 1H), 6.09 (d, *J* = 46.6 Hz, 1H), 1.39−1.34 (m, 2H), 1.32−1.28 (m, 1H), 1.07−1.02 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −179.84 (d, *J* = 46.5 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 199.5, 141.5, 140.4, 136.1 (d, *J* = 22.0 Hz), 128.8, 127.6, 127.1 (d, *J* = 5.1 Hz), 126.4 (d, *J* = 7.7 Hz), 91.3 (d, *J* = 174.6 Hz), 36.0 (d, *J* = 26.4 Hz), 13.42 (d, *J* = 3.0 Hz), 11.26 (d, *J* = 5.2 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{17}H_{15}FONa$, 277.0999; found, 277.0988.

*1-(Fluoro(naphthalen-1-yl)methyl)cyclopropane-1-carbaldehyde (**2v**).* Following the general procedure D, product **2v** was obtained in 40% yield (18.4 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 110:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.38). ^{1}H NMR (500 MHz, chloroform-*d*): δ 9.14 (s, 1H), 7.90−7.81 (m, 2H), 7.74−7.69 (m, 1H), 7.57−7.45 (m, 4H), 7.20 (d, *J* = 46.8 Hz, 1H), 1.36−1.30 (m, 2H), 1.20−1.16 (m, 1H), 0.47−0.41 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −177.47 (dd, *J* = 46.8, 7.0 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 199.4, 133.3, 131.7 (d, *J* = 20.0 Hz), 129.9 (d, *J* = 4.7 Hz), 129.1, 129.0, 126.7, 126.0, 125.0, 123.2 (d, *J* = 11.9 Hz), 122.8, 87.5 (d, *J* = 173.4 Hz), 36.0 (d, *J* = 27.7 Hz), 14.7 (d, *J* = 3.9 Hz), 10.5 (d, *J* = 4.7 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{15}H_{13}FONa$, 251.0843; found, 251.0843.

*4-Fluoro-4-phenylbutan-2-one (**3**).* Following the general procedure C, product **3** was obtained in 32% yield (10.6 mg) as a yellow oil after column chromatography (eluent = petroleum ether/EtOAc 40:1 v/v), (PE/EA = 20/1, $R_F \approx$ 0.30). ^{1}H NMR (500 MHz, chloroform-*d*): δ 7.42−7.31 (m, 5H), 5.94 (ddd, *J* = 46.9, 8.8, 3.9 Hz, 1H), 3.20 (ddd, *J* = 16.7, 14.7, 8.8 Hz, 1H), 2.82 (ddd, *J* = 32.1, 16.7, 4.0 Hz, 1H), 2.21 (s, 3H).

*Methyl 4-(Fluoro(1-(hydroxymethyl)cyclopropyl)-methyl)-benzoate (**4**).* According to the known procedure,[25] to a solution of **2b** (0.2 mmol, 47.2 mg, 1.0 equiv) in MeOH (3 mL) was added $NaBH_4$ (15.1 mg, 0.4 mmol, 2.0 equiv) at 0 °C, and the reaction mixture was stirred at the same temperature for 15 min. The mixture was poured into H_2O and extracted with EtOAc. The organic layer was washed with brine and dried with Na_2SO_4. After the removal of the solvent, the residue was subjected to column chromatography (petroleum ether/EtOAc = 5:1→2:1) to give compound **4** as a yellow oil in 93% yield (44.1 mg). ^{1}H NMR (400 MHz, chloroform-*d*): δ 8.04 (d, *J* = 8.1 Hz, 2H), 7.42 (d, *J* = 8.1 Hz, 2H), 5.50 (d, *J* = 47.0 Hz, 1H), 3.92 (s, 3H), 3.68 (d, *J* = 11.3 Hz, 1H), 3.31 (d, *J* = 12.4 Hz, 1H), 0.81−0.74 (m, 1H), 0.70−0.57 (m, 3H). ^{19}F NMR (471 MHz, chloroform-*d*): δ −180.89 (d, *J* = 47.8 Hz). ^{13}C{^{1}H} NMR (101 MHz, chloroform-*d*): δ 166.7, 142.9 (d, *J* = 22.4 Hz), 130.1, 129.5, 125.7 (d, *J* = 8.0 Hz), 96.6 (d, *J* = 174.5 Hz), 66.4, 52.2, 26.8 (d, *J* = 25.0 Hz), 8.8 (d, *J* = 4.4 Hz), 7.3 (d, *J* = 6.5 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{13}H_{15}FO_3Na$, 261.0897; found, 261.0886.

*1-(Fluoro(4-(methoxycarbonyl)phenyl)methyl)-cyclopropane-1-carboxylic Acid (**5**).* According to the known procedure,[25] compound **2b** (0.2 mmol, 47.2 mg) was dissolved in DMF (3 mL). Oxone (245.0 mg, 0.8 mmol, 4.0 equiv) was added in one portion and stirred at room temperature for 16 h. 1 N HCl was used to dissolve the salts, and EtOAc was added to extract the products. The organic extract was washed with 1 N HCl and brine and dried over Na_2SO_4, and the solvent was removed under reduced pressure to obtain the crude product. The crude mixture was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give compound **5** as a white solid in 84% yield (42.2 mg). ^{1}H NMR (500 MHz, chloroform-*d*): δ 8.03 (d, *J* = 7.9 Hz, 2H), 7.41 (d, *J* = 8.0 Hz, 2H), 6.13 (d, *J* = 46.6 Hz, 1H), 3.92 (s, 3H), 1.48−1.34 (m, 2H), 1.25−1.20 (m, 1H), 0.89−0.80 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −180.30 (d, *J* = 46.6 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 179.0, 166.7, 142.3 (d, *J* = 21.6 Hz), 130.2, 129.5, 126.2, 126.2, 90.9 (d, *J* = 176.1 Hz), 52.2, 27.5 (d, *J* = 26.9 Hz), 14.6 (d, *J* = 3.0 Hz), 12.6 (d, *J* = 5.0 Hz). HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{13}H_{13}FO_4Na$, 275.0690; found, 275.0686.

*Methyl 4-(Fluoro(1-(methoxycarbonyl)cyclopropyl)-methyl)-benzoate (**6**).* According to the known procedure,[25] compound **2b** (0.2 mmol, 47.2 mg) was dissolved in MeOH (3 mL). Oxone (245.0 mg, 0.8 mmol, 4.0 equiv) was added in one portion and stirred at room temperature for 48 h. 1 N HCl was used to dissolve the salts, and EtOAc was added to extract the products. The organic extract was washed with 1 N HCl and brine and dried over Na_2SO_4, and the solvent was removed under reduced pressure to obtain the crude

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J. Org. Chem. 2021, 86, 6800−6812

product. The crude mixture was purified by silica gel column chromatography (petroleum ether/EtOAc = 10:1) to give compound **6** as a colorless oil in 61% yield (32.5 mg). ^{1}H NMR (400 MHz, chloroform-*d*): δ 8.02 (d, J = 8.1 Hz, 2H), 7.41 (d, J = 8.2 Hz, 2H), 6.11 (d, J = 46.7 Hz, 1H), 3.91 (s, 3H), 3.66 (s, 3H), 1.41−1.34 (m, 1H), 1.34−1.26 (m, 1H), 1.18−1.08 (m, 1H), 0.83−0.75 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −180.03 (d, J = 46.9 Hz).^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 172.9 (d, J = 2.7 Hz), 166.6, 142.6 (d, J = 21.5 Hz), 130.1, 129.4, 126.2, 126.1, 91.5 (d, J = 175.6 Hz), 52.2 (d, J = 3.8 Hz), 27.6 (d, J = 26.6 Hz), 13.7 (d, J = 2.9 Hz), 11.8 (d, J = 5.2 Hz). HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{14}H_{15}FO_4Na$, 289.0847; found, 289.0836.

*Methyl (E)-4-((1-(3-Ethoxy-3-oxoprop-1-en-1-yl)cyclopropyl)-fluoromethyl)-benzoate (**7**).* According to the known procedure,[25] a solution of **2b** (0.2 mmol, 47.2 mg) and (ethoxycarbonylmethylene)-triphenylphosphorane (0.3 mmol, 1.5 equiv) in toluene (0.5 mL) was stirred in a sealed tube reactor at 110 °C in a metal bath for 18 h. The crude mixture, without aqueous workup, was directly purified by flash column chromatography (petroleum ether/EtOAc = 20:1→15:1) to give compound 7 as a yellow oil in 66% yield (40.5 mg). ^{1}H NMR (400 MHz, chloroform-*d*): δ 8.04 (d, J = 8.1 Hz, 2H), 7.43 (d, J = 8.1 Hz, 2H), 6.85 (d, J = 15.9 Hz, 1H), 5.69 (d, J = 15.9 Hz, 1H), 5.37 (d, J = 46.7 Hz, 1H), 4.13 (q, J = 7.1 Hz, 2H), 3.92 (s, 3H), 1.24 (t, J = 7.1 Hz, 3H), 1.20−1.16 (m, 1H), 1.10−0.98 (m, 3H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −178.08 (d, J = 47.4 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 166.5 (d, J = 31.3 Hz), 149.1, 142.4 (d, J = 21.9 Hz), 130.2, 129.7, 126.1, 126.0, 119.2, 95.8 (d, J = 178.0 Hz), 60.3, 52.2, 25.9 (d, J = 26.2 Hz), 15.0 (d, J = 3.1 Hz), 14.2, 13.2 (d, J = 6.2 Hz). HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{17}H_{19}FO_4Na$, 329.1160; found, 329.1142.

*Methyl 4-(Fluoro(1-((phenylamino)methyl)-cyclopropyl)methyl)-benzoate (**8**).* According to the known procedure,[11] to a stirred solution of **2b** (0.2 mmol, 47.2 mg) and $PhNH_2$ (74.4 mg, 0.8 mmol, 4.0 equiv) in methanol (1 mL) at room temperature were added sodium cyanoborohydride (25.2 mg, 0.4 mmol, 2.0 equiv) and zinc chloride (13.4 mg, 0.1 mmol, 0.5 equiv). The resulting solution was stirred at room temperature for 3 h and was taken up in 0.1 N NaOH (2 mL). After methanol was evaporated under reduced pressure, the aqueous solution was extracted with ethyl acetate three times. The combined organic layer was washed with water and brine, dried over anhydrous $MgSO_4$, and evaporated to dryness. The residue was purified by column chromatography (petroleum ether/EtOAc = 5:1) to produce compound **8** as a yellow oil in 86% yield (53.7 mg). ^{1}H NMR (500 MHz, chloroform-*d*): δ 8.03 (d, J = 7.9 Hz, 2H), 7.46−7.39 (m, 2H), 7.14 (t, J = 7.1 Hz, 2H), 6.69 (t, J = 7.3 Hz, 1H), 6.50 (d, J = 7.9 Hz, 2H), 5.36 (d, J = 46.8 Hz, 1H), 3.92 (s, 1H), 3.23 (d, J = 12.6 Hz, 1H), 2.78 (dd, J = 12.5, 1.3 Hz, 1H), 0.88−0.81 (m, 1H), 0.79−0.72 (m, 2H), 0.71−0.65 (m, 1H). ^{19}F NMR (376 MHz, chloroform-*d*): δ −179.26 (dd, J = 46.5, 5.4 Hz). ^{13}C{^{1}H} NMR (126 MHz, chloroform-*d*): δ 166.7, 148.3, 143.0 (d, J = 22.1 Hz), 130.0, 129.6, 129.2, 125.6, 125.5, 117.4, 112.6, 97.9 (d, J = 175.3 Hz), 52.2, 47.9, 24.6 (d, J = 25.4 Hz), 9.5 (d, J = 4.1 Hz), 8.6 (d, J = 7.9 Hz). HRMS (ESI-TOF) m/z: [M + K]$^+$ calcd for $C_{19}H_{20}FNO_2K$, 352.1110; found, 352.1104.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.1c00578.

Details on the optimization of reaction conditions for compound **1o-Bz**, HPLC spectra of compound **2b**, and NMR spectra of all new compounds (PDF)

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Notes

The authors declare no competing financial interest.

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